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EXPLOSIVE DECOMPRESSION STUDIES WITH ANIMALS WEARING FULL BLADDER SUIT AND HELMET

DONALD A. ROSENBAUM

AERO MEDICAL LABORATORY

NOVEMBER 1957

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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PROJECT NO. 7160
TASK NO. 71814

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

The work reported herein was performed in support of Project 7160, "High Altitude Physiology," Task 71814, "Establishment of Physiological Requirements for Cabin Pressurization Systems and Explosive Decompression Protection." This study was conducted in the Physiology Branch of the Aero Medical Laboratory, Wright Air Development Center.

The author wishes to thank Capt. Dale Smith, USAF (VC) and Lt. Keith Kraner, USAF (VC), for their selection, care and follow-up study on the animals. Their help with the actual animal experiments was greatly appreciated. Capt. James Prine, USAF (VC), performed all postmortem examinations and was responsible for the microscopic studies. Mr. Al Curtis was responsible for the excellent color photography.

The animal experimentation reported herein was performed according to the "Rules Regarding Animal Care" as approved by the American Medical Association.

ABSTRACT

Studies on 17 dogs, wearing a full bladder suit and helmet while connected to an automatic oxygen regulator, show that no apparent residual pulmonary pathology results following explosive decompression (30 msec) through 10 psi and 14 psi. Possible reasons for the essentially normal appearing pulmonary condition are discussed.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Laboratories

Figure 1. FULL BLADDER ANIMAL SUIT (MC-3 TYPE) AND HELMET WORN DURING THE EXPLOSIVE DECOMPRESSION STUDIES

EXPLOSIVE DECOMPRESSION STUDIES WITH ANIMALS WEARING FULL BLADDER SUIT AND HELMET

INTRODUCTION

The pathological effects of explosive decompression have been described by many authors.[1-12] All workers report pulmonary damage such as, atelectasis, emphysema and collapsed alveoli. Some report hemorrhage and fluid in the lung.

Previous work in this and other laboratories[12] has shown that the addition of a binding or a suit to the thoracic cage which restricts chest expansion causes more pulmonary damage than that occurring in an unrestricted animal. However, no experiments have been reported in which the animal was wearing the suit and helmet while breathing safety pressure from an automatic regulator.

This preliminary study is an attempt to assess any permanent pulmonary damage resulting from explosive decompression to animals wearing a full bladder type suit and breathing helmet.

METHODS

Seventeen normal, healthy dogs were used. Because only two sizes of animal suits were available, it was necessary to use animals weighing between 10 and 14 kg. The animals were fitted to the suits before being chosen for the experiments. They were held in quarantine for 28 days during which time blood tests, histoplasmosis checks, x-rays and standard physical tests were completed on all animals.

Following the quarantine period, the animals were repeatedly fitted with the pressure equipment, not only to acquaint them with the suit and helmet, but also to reduce apprehension. In addition, they were taken near the altitude chamber during altitude runs to expose them to the chamber noises. This too, was done to alleviate fear and nervousness of the animals.

The seventeen dogs were divided into three groups for this study. In Group I there were eight animals. This group was decompressed through 10 psi (from 8,000 to 65,000 feet) in 28 msec. After the experimental procedures, autopsy was performed on three; five were allowed to live and were followed clinically.

The six animals in Group II were decompressed through 14 psi (from ground level to 70,000 feet) in 30 msec. Three of this group were autopsied and three followed clinically. All of the animals survived the decompressions.

Group III was composed of three animals which were decompressed through 10 psi (from 8,000 to 65,000 feet) in order to measure suit bladder and mask pressures. All of the animals in Groups I, II and III survived the decompression.

In the first two series, the animals were run as pairs. Each pair was matched approximately according to weight, age and size. Blood samples and chest x-rays were taken before the experimental run. One animal of each pair was nembutalized following the run and autopsied. The other was allowed to live and followed clinically.

Each dog was fitted in the full bladder suit (fig. 1). Care was taken to prevent abnormal restriction of breathing. The neck piece and helmet were placed on the animal. The dog was then placed in a kneeling position on a dog board which was padded to minimize leg discomfort. Both legs were tied to the board, and a restraining gauze strip was spiraled around the dog's body and the board. Finally, the helmet was securely fixed to the board. The animal was then placed in the chamber and the oxygen inlet hose attached to the bladder suit. The oxygen helmet was plugged into the opposite side of the bladder suit, so that the animal breathed through the bladder system. The animal breathed 100% oxygen under safety pressure from a Bendix MB-3 regulator which had the capstan outlet blocked.

The decompression chamber was a 27-cubic-foot section of a sphere with a 27-inch orifice. This chamber was in a large altitude chamber (2400 cubic foot volume). The animal-chamber orifice was sealed with layers of brown wrapping paper and wax paper. The thickness of the paper used had been previously determined for each differential. After the required altitudes were reached, decompression was accomplished by the electrical firing of an expanding cartridge. This cartridge ruptured the paper seals and an explosive decompression of 30 msec or less resulted. Following the decompression, the animal remained at peak altitude for 30 seconds, and then was brought to ground level in three minutes. The animals on which autopsy was to be performed were sacrificed with nembutal.

In Group III, pressures were measured during and following a 10 psi decompression. The bladder pressure was measured from a T-in regulator-bladder line, next to the bladder. The mask pressure was measured from a tap in the breathing helmet. Pressures were measured with Clarke capsules and recorded on a Miller oscillograph.

RESULTS

All animals were alive and seemingly normal immediately after reaching ground level. In the autopsied animals, no significant gross pathology could be seen. All animals were essentially normal. Microscopic examinations have not been completed. In the animals which were followed clinically, all physical examinations, including blood and x-ray studies were normal for a six-week period after the decompression. This was true in both 10 and 14 psi differentials. Case histories, including pathology and physical examination records, of the experimental animals are given in the appendix.

Bladder and mask pressures peaked at 235 mm Hg (± 15 mm Hg), and were never more than 15 mm apart. Thus, during the decompression there was apparently never more than 15 mm Hg positive pressure in the lungs.

DISCUSSION

Figure 3 shows the lungs of a normal dog, one of four control animals previously run, decompressed through 10 psi (8,000-65,000 ft). Atelectasis is evident and areas of emphysema can be seen in the apical lobes. This animal wore no altitude pressure equipment.

Figure 4 shows the lungs of an animal wearing the full bladder suit and helmet, also decompressed through 10 psi. The lack of gross pathology, atelectasis and emphysema is quite evident.

Two suppositions can be made regarding the normal appearance and condition of the dog's lungs following the decompression. First, no damage occurred; or second, the damage which occurred was reversed or compensated for by the high breathing pressure delivered to the suit and helmet following the decompression. Each supposition has some experimental evidence to substantiate it.

As to the first theory, the pressure records (see fig. 2) show that both breathing and counterpressure change at the same rate and to the same degree (±15 mm Hg unbalance). This balance of pressures is due to the compensated breathing valve. Because of its construction and its position in the breathing circuit, the mask pressure is on one side of the valve and the bladder pressure on the other side. If lung, thence mask pressures become greater than bladder pressure, the valve "dumps" the excess mask pressure. If bladder pressure is higher, then oxygen is forced into the mask (lungs) until the pressures are balanced. Thus, no differential of pressure exists between lungs and counterpressure, and no change is expected. However, the balance depends on a reliable exhalation valve which can respond fast enough to balance these pressures.

The second supposition is that the atelectasis occurs and that the high breathing pressures delivered by the regulator alleviate or reinflate the atelectasis. Lutz [13] recomended positive pressure breathing (30 mm Hg) to inflate the decompression atelectasis. Studies in this Laboratory have demonstrated that the apparent pathology of decompression can be alleviated by inflation of the lungs. Figure 5 shows the lung of an animal decompressed through 5 psi as it was taken from the chest and figure 6 shows the same lung after inflation with positive pressure air. This was an anesthetized animal with a tracheal cannula and wearing the full bladder suit and helmet. Small amounts of gross pathology can be seen, but the inflated lung is essentially normal.

Figure 7 shows the lungs of an animal decompressed from ground level to 22,000 feet in approximately 18 msec. The animal was anesthetized, but had a tracheal cannula, and was wearing the full bladder suit, helmet and was breathing safety pressure. Although the differential was only 8.5 psi, there is more gross damage in this animal than those decompressed through 14 psi, wearing the suit and helmet while breathing safety pressure. At 22,000 feet, the regulator does not deliver positive pressure. At 65,000 feet the level-off altitudes for the 10 and 14 psi differentials, a positive pressure of 120 mm Hg is delivered to the lungs and bladder system.

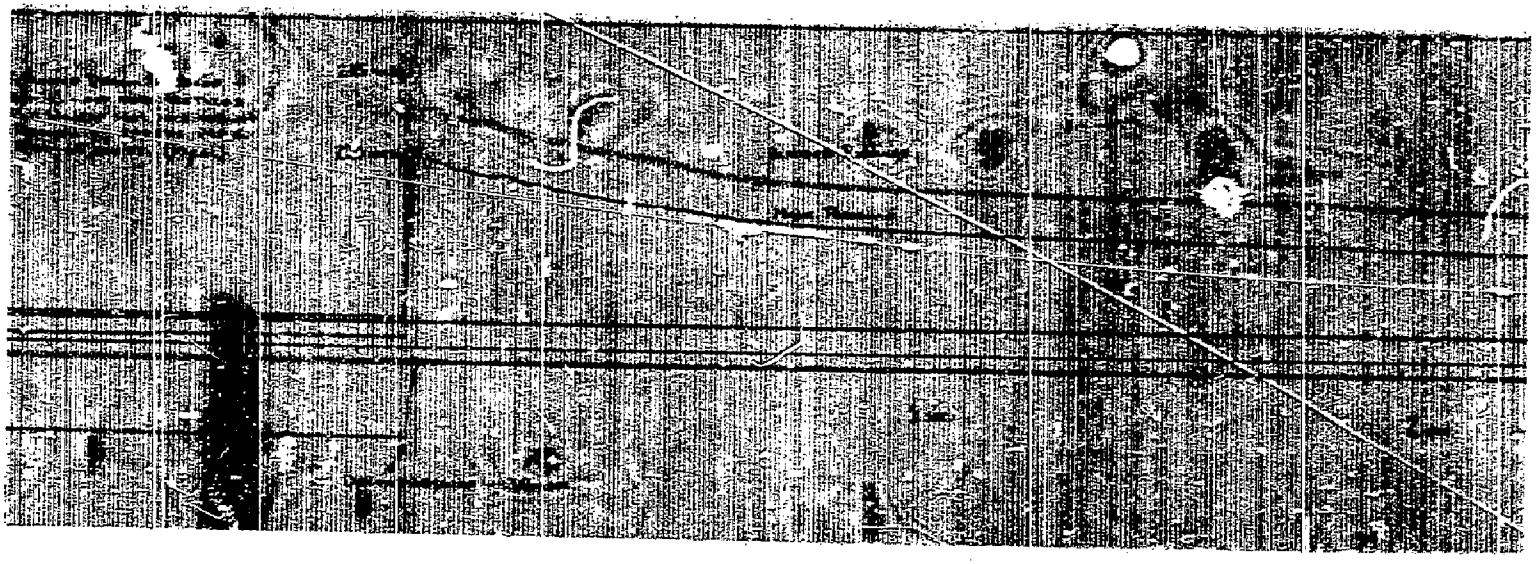

Figure 2. EXPLOSIVE DECOMPRESSION - ANIMAL NOT ANESTHETIZED - WEARING FULL BLADDER SUIT AND HELMET - BREATHING SAFETY PRESSURE - 8,000 to 65,000 feet (10 psi)

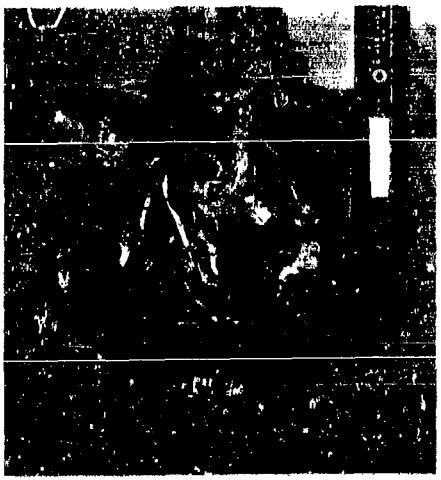

Figure 3. **LUNGS OF A NORMAL DOG DECOMPRESSED THROUGH 10 PSI.** This animal wore no altitude pressure equipment. Atelectasis is evident and areas of emphysema can be seen in the apical lobes.

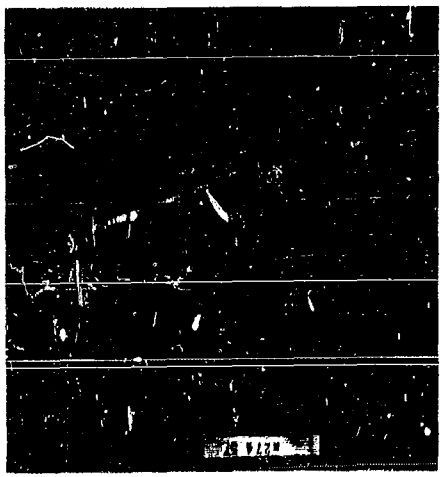

Figure 4. **LUNGS OF A NORMAL DOG DECOMPRESSED THROUGH 10 PSI.** This animal wore the full bladder suit and helmet while breathing from a modified MB-3 regulator. Lack of gross pathology, atelectasis, and emphysema is evident.

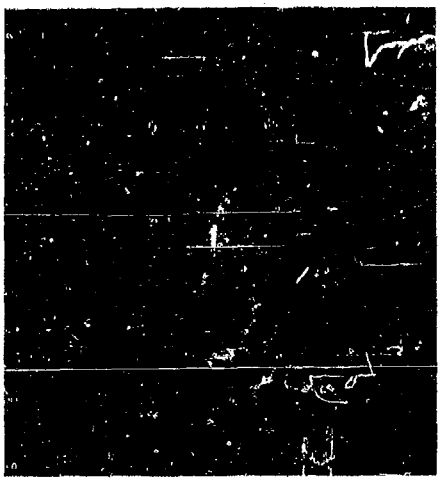

Figure 5. **LUNG OF A NORMAL DOG DECOMPRESSED THROUGH 5 PSI, AS IT WAS TAKEN FROM CHEST.**

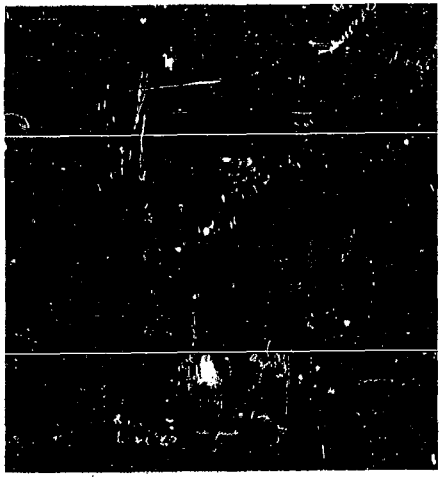

Figure 6. **SAME LUNG SHOWN IN FIGURE 5 AFTER INFLATION WITH POSITIVE PRESSURE AIR.**

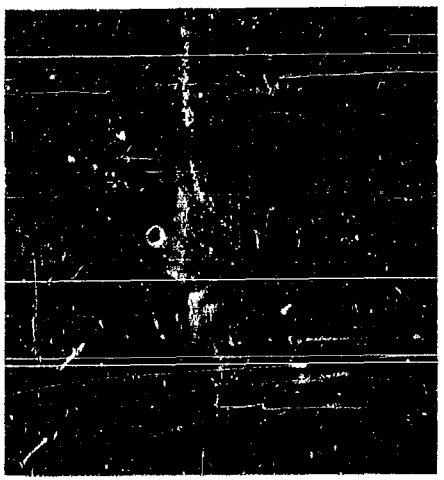

Figure 7. **LUNGS OF A NORMAL DOG DECOMPRESSED FROM GROUND LEVEL TO 22,000 FEET IN APPROXIMATELY 18 MSEC** (See text.)

This study, although not complete, supports the second supposition, in that if pulmonary atelectasis does occur, it is alleviated by the reinflation of the lungs by the positive pressure delivered by the regulator.

SUMMARY AND CONCLUSIONS

1. Unanesthetized animals, wearing a full bladder suit and helmet suitably connected to an oxygen regulator, show no significant gross pathology following explosive decompression through 10 and 14 psi.

2. Mask and bladder pressures, measured in three animals, show both pressures to respond to the same peak pressure at the same rate.

3. Two possible explanations for the essentially normal appearing lung fields, following decompression, are discussed.

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APPENDIX

CASE HISTORIES OF THE EXPERIMENTAL ANIMALS

GROUP I

Dog No. 789	Male	27 Pounds
25 Apr 57	Histoplasmosis Negative	
15 Jul 57	Normal blood count Normal chest x-rays Decompressed from 12,500 to 65,000 feet with full pressure suit protection in 28-30 msec. Held at altitude 30 seconds. Dropped in three minutes, appeared normal, PTS. Necropsy revealed only hemorrhage in middle ears.	

Dog No. 494	Female	22 Pounds
15 Mar 56	Fecal Examination Negative Leptospirosis Serology Negative Normal blood count	
12 Apr 57	Histoplasmosis Negative	
15 Jul 57	Explosive decompression from 12,500 to 65,000 feet (10 psi) in 28-30 msec. Full Pressure Suit. Chest x-rays before and after - Normal Blood counts before and after - Normal	
16 Jul 57	Physical Examination - Normal	
17 Jul 57	" " "	
18 Jul 57	" " "	
19 Jul 57	" " "	
4 Sep 57	" " "	

GROUP I (cont'd)

Dog No. 771	Female	25 Pounds
22 Apr 57	Histoplasmosis Negative	
15 Jul 57	Normal blood count Normal chest x-rays	
16 Jul 57	Decompressed through 10 psi in 28-30 msec with full pressure suit protection. Held at altitude 30 seconds, dropped in 3 minutes. Appeared normal. Necropsy revealed only slight middle ear hemorrhage.	

Dog No. 746	Female	27 Pounds
20 Feb 57	Fecal Examination shows ascarids (Toxocara canis)	
25 Feb 57	Blood count Normal	
27 Feb 57	Leptospirosis serology - Negative	
16 Jul 57	Explosive decompression (8,000 to 65,000 feet in 28-30 msec) full pressure suit protection. Chest x-rays before and after - Normal Blood counts before and after - Normal	
17 Jul 57	Complete Physical Examination - Normal	
18 Jul 57	" " " "	
19 Jul 57	" " " "	
4 Sep 57	" " " "	

Dog No. 763	Male	23 Pounds
5 Jun 57	Normal blood count	
25 Jun 57	Leptospirosis serology - Negative	
12 Jul 57	Chest x-rays normal	
16 Jul 57	Normal blood count	
17 Jul 57	Decompressed through 10 psi in 28-30 msec, full pressure suit protection. Held at altitude 30 seconds, dropped in 3 minutes. Brief examination - Negative Necropsy revealed only slight middle ear hemorrhage.	

GROUP I (cont'd)

Dog No. 586	Female	25 Pounds
22 Oct 56	Leptospirosis Serology Negative	
22 Apr 57	Histoplasmosis Negative	
17 Jul 57	Explosive decompression from 8,000 to 65,000 feet in 28-30 msec, full pressure suit Chest x-rays before and after - Normal Blood counts before and after - Normal	
18 Jul 57	Physical Examination - Normal	
19 Jul 57	" " "	
22 Jul 57	" " "	
12 Aug 57	" " "	

Dog No. 664	Female	29 Pounds
22 Apr 57	Histoplasmosis Negative	
18 Jul 57	Explosive decompression from 8,000 to 65,000 feet in 28-30 msec, full pressure suit. Chest x-rays before and after - Normal Blood counts before and after - Normal	
19 Jul 57	Physical Examination - Normal	
22 Jul 57	" " "	
23 Jul 57	" " "	
12 Aug 57	" " "	
4 Sep 57	" " "	

Dog No. 726	Female	20 Pounds
7 Dec 56	Leptospirosis serology - Negative	
13 Dec 56	Fecal examination revealed Hookworm (Ancylostoma caninun)	
22 Apr 57	Histoplasmosis Negative	
18 Jul 57	Explosive decompression (8,000 to 65,000 feet in 28-30 msec) in full pressure suit. Chest x-rays before and after - Normal	

GROUP I (cont'd)

Dog No. 728 (cont'd)	Female	20 Pounds
18 Jul 57	Blood counts before and after - Normal	
19 Jul 57	Physical Examination - Normal	
22 Jul 57	" " "	
23 Jul 57	" " "	
4 Sep 57	" " "	

GROUP II

Dog No. 849	Female	20 Pounds
2 Jul 57	Normal blood count Histoplasmosis Negative Leptospirosis serology - Negative	
12 Aug 57	Decompressed from 2,500 to 72,000 feet in 30-35 msec in full pressure suit. Held at altitude 30 seconds, dropped in 3 minutes. Dog appeared normal. Necropsy revealed only slight middle ear hemorrhage.	

Dog No. 805	Female	20 Pounds
12 Jun 57	Blood count - Normal Leptospirosis serology - Negative	
17 Jun 57	Histoplasmosis Negative	
12 Aug 57	Explosive decompression (0 to 36,000 feet in 28-30 msec) 11 psi in full pressure suit	
13 Aug 57	Complete Physical Examination - Normal	
14 Aug 57	" " " "	
15 Aug 57		
16 Aug 57	" " " "	
19 Aug 57	" " " "	
20 Aug 57	" " " "	
4 Sep 57	" " " "	

GROUP II (cont'd)

Dog No. 850	Female	20 Pounds
2 Jul 57	Normal blood count Histoplasmosis Negative	
13 Aug 57	Decompressed through 14 psi in 30-35 msec with full pressure suit protection. Held at altitude 30 seconds, dropped in 3 minutes. Appeared normal after run. Necropsy revealed only slight middle ear hemorrhage.	

Dog No. 817	Female	23 Pounds
19 Jun 57	Physical Examination - Normal	
23 Jun 57	Histoplasmosis Negative	
2 Jul 57	Blood count - Normal Leptospirosis serology - Negative	
13 Aug 57	Explosive decompression (0 to 72,000 feet in 30-35 msec) 14 psi, full pressure suit.	
14 Aug 57	Complete Physical Examination - Normal	
15 Aug 57	" " " "	
16 Aug 57	" " " "	
19 Aug 57	" " " "	
20 Aug 57	" " " "	
4 Sep 57	" " " "	

Dog No. 748	Female	24 Pounds
25 Feb 57	Normal blood count Leptospirosis serology - Negative	
26 Apr 57	Histoplasmosis Negative	
14 Aug 57	Decompressed from ground to 72,000 feet in 30-35 msec (14 psi) with full pressure suit. Held at altitude 30 seconds, dropped in 3 minutes. Briefly examined and found normal, immediately sacrificed with nembutal. Gross necropsy examination revealed only damage to be slight middle ear hemorrhage.	

GROUP II (cont'd)

Dog No. 819	Female	21 Pounds
25 Jun 57	Physical Examination - Normal	
2 Jul 57	Blood count - Normal Leptospirosis serology - Negative Histoplasmosis Negative	
14 Aug 57	Explosive decompression (2,500 to 72,000 feet in 30-35 msec) 13 psi, full pressure suit.	
14 Aug 57	Complete Physical Examination - Negative	
16 Aug 57	" " " "	
19 Aug 57	" " " "	
20 Aug 57	" " " "	
21 Aug 57	" " " "	
4 Sep 57	" " " "	

GROUP III

Dog No. 841	Male	20 Pounds
2 Jul 57	Normal blood count Leptospirosis serology Negative Histoplasmosis Negative	
12 Sep 57	Explosive decompression through 10 psi in 28-30 msec with full pressure suit and mask and suit pressures taken. Held 30 seconds at altitude with 3 minutes to drop.	
13 Sep 57	Physical Examination Normal	
16 Sep 57	" " "	
17 Sep 57	" " "	
18 Sep 57	" " "	

GROUP III (cont' d)

Dog No. 846	Male	30 Pounds
2 Jul 57	Histoplasmosis Negative	
8 Jul 57	Leptospirosis serology - Negative Normal blood count	
12 Sep 57	Explosive decompression through 10 psi with full pressure suit protection and mask and suit pressures taken. Held at altitude 30 seconds, dropped in 3 minutes.	
13 Sep 57	Physical Examination Normal	
15 Sep 57	" " "	
17 Sep 57	" " "	
18 Sep 57	" " "	

Dog No. 775	Female	23 Pounds
29 Mar 57	Fecal examination revealed hook worms Vermiplex given to eliminate worms	
10 Apr 57	Leptospirosis serology Negative Normal blood count	
25 Apr 57	Histoplasmosis Negative	
12 Sep 57	Explosive decompression through 10 psi with full pressure suit protection and pressures of mask and suit measured. Maintained at altitude 30 seconds, dropped in 3 minutes.	
13 Sep 57	Complete Physical Examination - Normal	
14 Sep 57	Normal Upon Examination	
15 Sep 57	" " " "	
16 Sep 57	" " " "	
17 Sep 57	" " " "	
19 Sep 57	" " " "	